THE USE OF MICROPROCESSORS
FOR TRACK CONTROL AND DATA VERIFICATION
ON HYDROGRAPHIC SURVEYS IN CANADA

by G. MACDONALD [*]

SUMMARY

In the mid-sixties the Canadian Hydrographic Service began to investigate methods of providing computer assistance to hydrographers that were using conventional data collection techniques. NAVBOX, a microprocessor-controlled survey aid, is a product of these investigations. It provides straight line navigation from a variety of positioning systems, and positions and depths are verified using software filters. First used on board helicopters and tracked vehicles in the Arctic, NAVBOX has been used on regular hydrographic surveys since 1977, and has a number of real and potential survey applications.

INTRODUCTION

In the mid-sixties the Canadian Hydrographic Service was beginning to consider methods of automating hydrographic surveys in Canada. In 1968, HYPOS, which stands for Hydrographic Position, was developed and used with some small success until 1973. Survey data was collected in the conventional manner, but echograms were mailed to a central processing station where soundings were scaled with a digitizer (see fig. 1a) and merged, by computer, with positions that had been transmitted via telex (see fig. 1b). In as little as two

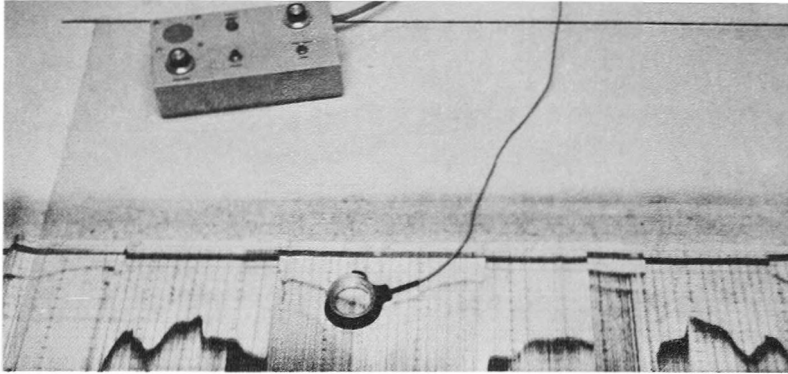(*) Canadian Hydrographic Service, Burlington, Ontario, Canada.
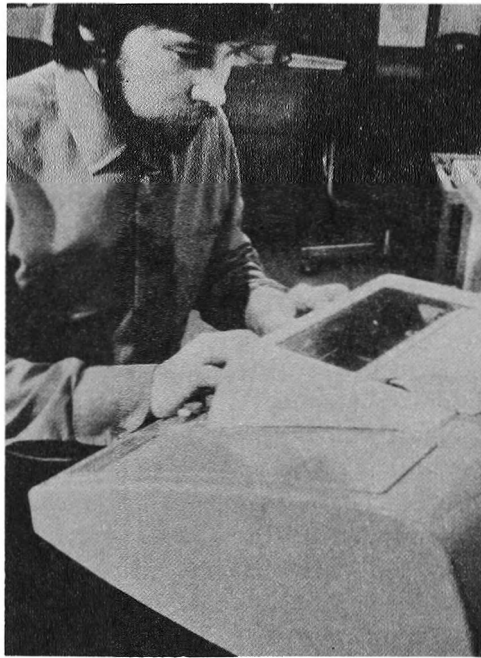
FIG. 1a. – Digitizing echograms for HYPOS.

FIG. 1b. – HYPOS positions transmitted via telex.

weeks' turnaround the sounding rolls, printout and sounding plot were back in the hands of the field hydrographer. Now all he had to do was find out where all the mistakes were, edit the data, and go through the whole process again. Not an impossible task, but hydrographers could see processing time, the ratio of bad data to good, and the number of required personnel all rise. There were some benefits the hydrographer did not see. Computer programs were developed to convert electronic positions, to plot soundings, to edit data and to produce field sheets. But, best of all, hydrographers were beginning to lift their sights from a cresting wave to a cresting technology that had possibilities of improving what some thought had already been perfected.
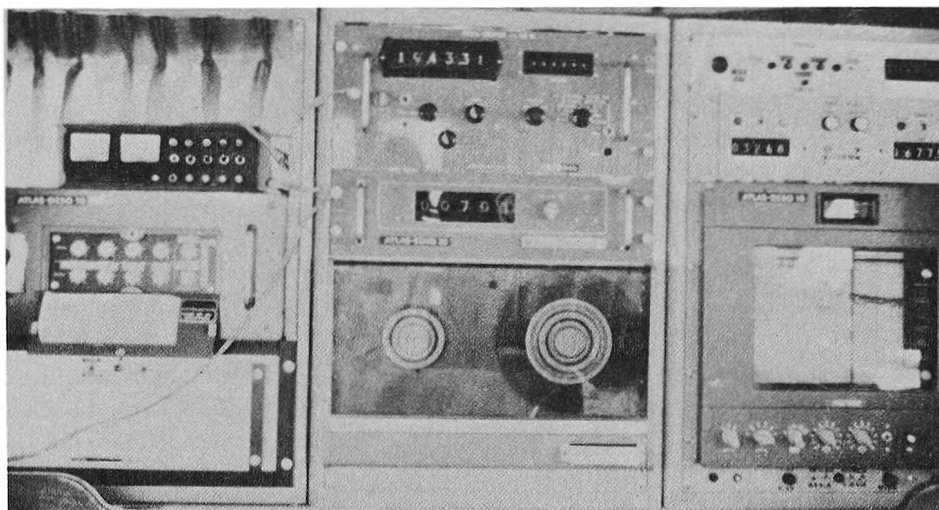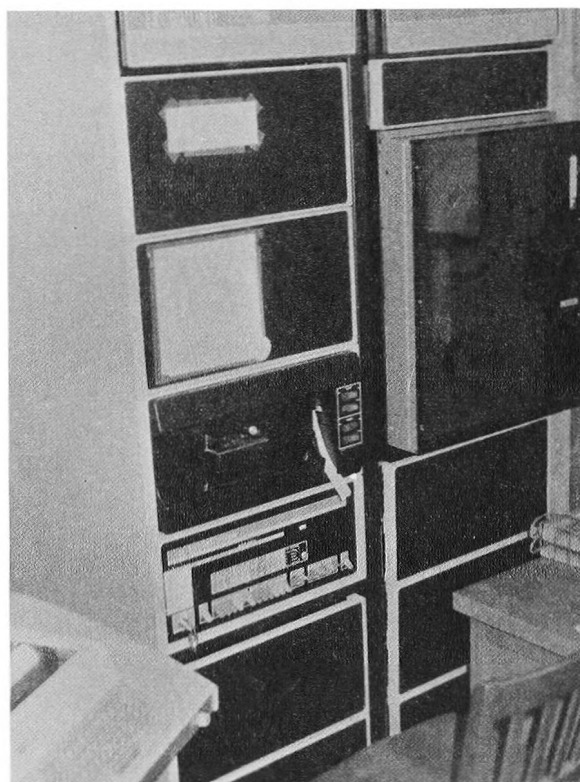
FIG. 2a. – HAAPS logging system.

FIG. 2b. – HAAPS processing system.

As challenging as it might have been, HYPOS did not work well. So in 1969, with the philosophy that if you cannot bring the hydrographer to the mountain, you can bring the mountain to the hydrographer, computers were introduced to the field with a system called HAAPS, an acronym for Hydrographic Acquisition and Processing System. Depths and positions were converted from analog to digital form on board the survey vessel (see fig. 2a), stored on magnetic tape, and processed off-line with a PDP-8 computer (see fig. 2b). This system had a lot of advantages. There was short turnaround time because the computer was in the field. The software needed to process the data was developed by hydrographers, for hydrographers. Soundings were selected, stored and plotted from a digital source in the field. But with all these advances there were still problems. The recorded data was unverified, so the hydrographer was unaware of any logging difficulties, until the computer had a look at the data during processing. By then it was often too late, since a problem may have gone days without being noticed, requiring either large areas to be resounded or the data to be manually recovered.

That's why, in 1974, INDAPS, the Integrated Navigation. Data Acquisition and Processing System, was developed (see fig. 3a). For the first time, a computer became part of the logging system and real time data verification and equipment checks were possible. Besides providing more reliable data, the computer logger provided a certain flexibility and versatility. It could tell the hydrographer exactly where he was and in what direction he was going. If the hydrographer in turn told the computer where he wanted to be and in which direction he wanted to go, the computer could provide steering instructions to get the hydrographer on line, and keep him there. Even though some hydrographers thought we were

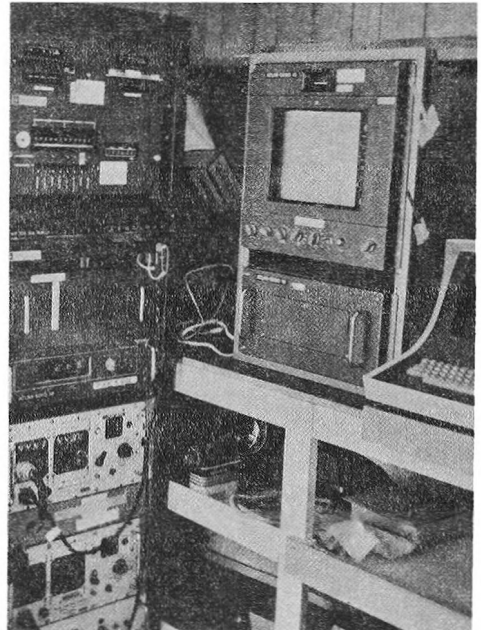FIG. 3a. – INDAPS was developed...

FIG. 3b. – INDAPS logger/processor.

FIG. 4. – PHAS system.

relying too heavily on something we did not completely understand, a few hydrographers were beginning to see some real benefits from all this development.

As good as INDAPS was, it still had its problems, not the least of which were its size, weight and high power requirement (see fig. 3b) – not at all suitable for a small launch. So an enterprising bunch of engineers put their heads together and designed PHAS, a Portable Hydrographic Acquisition System (see fig. 4). It was small, light weight, easy to use and had a low power requirement. Since it was computer-based it performed data checks on depths and positions. But it had no printer, an inadequate data display, and no way to navigate. So where did all this lead ? It led to NAVBOX.

NAVBOX

Because PHAS did not navigate; because INDAPS was bulky, heavy and needed lots of power; because HAAPS had no on-board computer to check data; and because HYPOS was so clumsy and cumbersome; INDAS, the Integrated Navigation and Data Acquisition System (which is the proper name for NAVBOX) was designed in the fall of 1976 and implemented in the spring of 1977 (see fig. 5). The box has three circuit boards; an SBC80-10 INTEL single board computer, a North Star Computer floating point arithmetic board and a custom designed board which contains a video display controller, a clock, additional memory, and peripheral interfaces. The other major components are a six-column
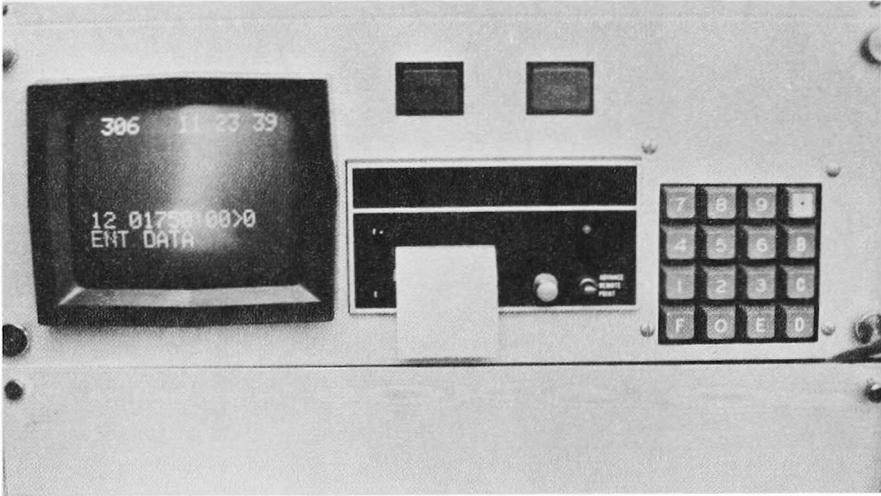
FIG. 5. – Prototype NAVBOX.

thermal printer, a 16-character keyboard and a five-inch TV monitor. The total package weighs thirty pounds, draws 3 amps at 24 volts, is inexpensive and is easy to use.

The software can handle hyperbolic positions from systems like Seafix or Minifix or range-range positions from Motorola Mini-Ranger or Del Norte Trisponder. The NAVBOX can operate as a stand-alone navigation unit directing survey vessels along lines or between points with no depth input and no data logging, or it can log position and depth without navigating, or it can log and navigate.

NAVBOX SOFTWARE

Straight Line Navigation

For a number of reasons (see fig. 6), hydrographers prefer to run straight lines instead of following lines of constant radio position. First, and most importantly, survey planning is much easier. Instead of worrying about which pattern has to be run so that depth contours will be crossed instead of followed, or worrying about manually conning the vessel to keep on a straight line, a problem compounded by rough seas, winds and currents, the hydrographer need only worry about the direction of his survey line, the point at which to start the first line, and the distance between lines. The NAVBOX (with a little help) will do the rest. Second, as a result of better planning, the survey becomes more efficient. In tests on the St. Lawrence River, thirty percent fewer sounding miles were run using computer-assisted straight-line navigation in an area previously controlled by lines of position. A ten percent saving in sounding miles can generally be realised. Third, the coxswain has a much easier time keeping the
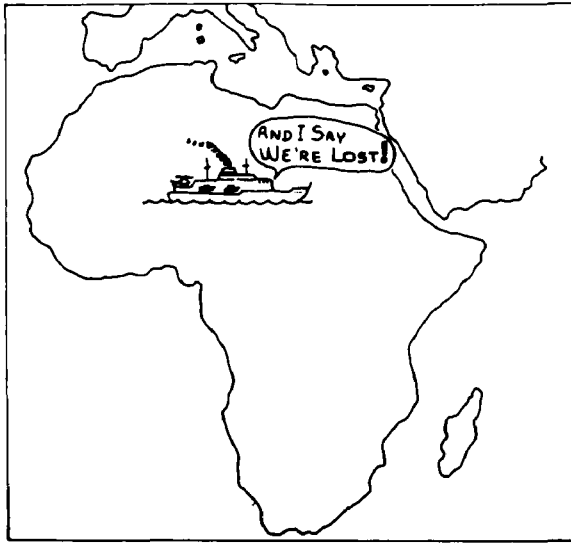
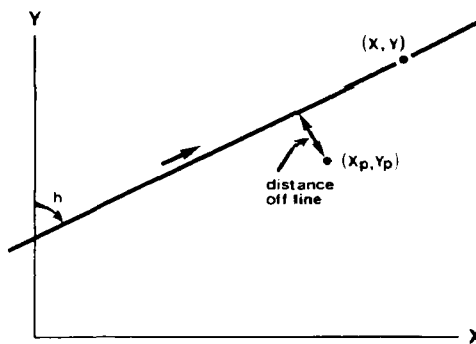FIG. 6. — Hydrographers prefer to run straight lines.

FIG. 7. — Straight line navigation.

vessel on line, and the hydrographer is freed from his conning chores and is able to better plan the immediate survey.

The mathematical solution to the problem of line-keeping is found in analytic geometry (see fig. 7). By defining the line to be run as an X, Y co-ordinate on the line and a heading, and substituting the position of the vessel (X_p, Y_p) in the straight line equation, the distance off line and the direction to steer to get back on line can be computed.

Then, each second, the time, pattern readings, northing and easting, distance off line, direction to steer and depth are displayed for the hydrographer on the NAVBOX TV monitor, and for the coxswain on a remote monitor (see fig. 8). Line reversal is a pushbutton operation from the front panel, and line spacing is a user-entered variable.
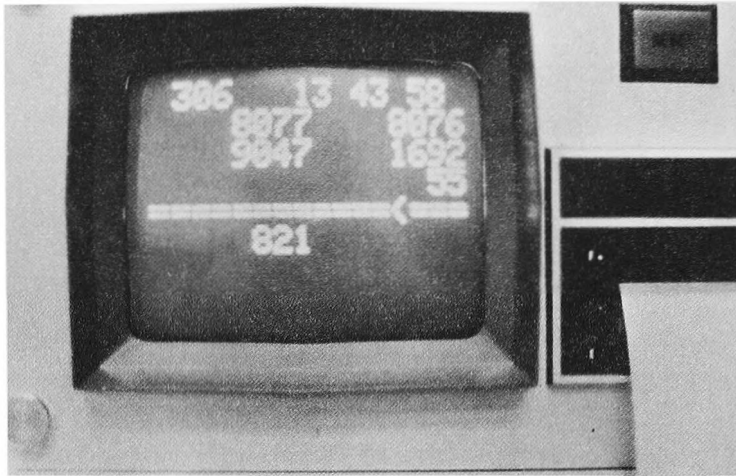
FIG. 8. – NAVBOX navigation display

day	time
pattern 1	pattern 2
northing	easting
	distance off line
	direction to steer
depth	

The general form of the straight line equation is :

$$AX + BY + C = 0$$

where :

A = cos h
B = – sin h
C = a constant equal to but opposite in sign to $AX + BY$ to balance the equation
X = easting of a point on the line
Y = northing of the same point on the line
h = heading of first sounding line.

If (X_p, Y_p), the present position of the vessel, is substituted in the line equation to replace (X, Y), the result will be the distance off line. A negative value indicates the vessel is too far to port.

On a line reversal (see fig. 9), X and Y are recomputed for the new line.

$$\triangle X = \text{line spacing } ^*A$$
$$\triangle Y = \text{line spacing } ^*B$$
$$\text{new } X = \text{old } X + \triangle X$$
$$\text{new } Y = \text{old } Y + \triangle Y$$

Then, to navigate on the new line the sign of A, B and the line spacing must be reversed, and a new value for C must be computed.
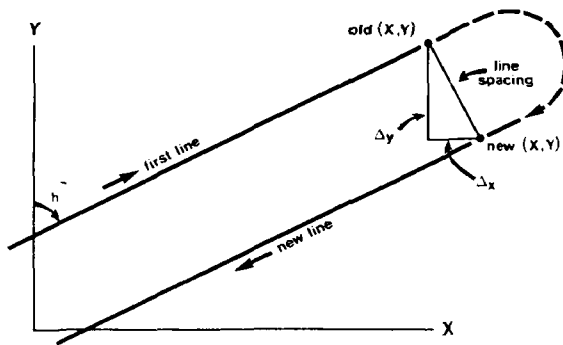
FIG. 9. – Line reversal.

Depth Filter

Now that the hydrographer is on line, he is extremely interested in collecting reliable data. To help ensure that recorded depths and positions are clean, software filters are used in the NAVBOX to reduce the amount of bad data. Depths and ranges are filtered by using a gating technique. The gate width is defined as the absolute acceptable difference between two successive values. The gate is set up around the previously accepted value. The current value will pass through the gate if it does not vary from the previous value by more than the gate width.

Here is how the depth gating technique works. Each depth received is checked against user defined minimum and maximum depths. This is useful, for instance if aeration is a problem during turns or rough seas, or if transmission noise is present. This preliminary check is necessary since sustained bad depths may eventually be accepted by the filter. Depths less than the minimum depth and greater than the maximum depth are discarded.

A permanent gate is symmetrically established around a good depth (see fig. 10). A new depth is compared to the gate limits and, if it falls within the gate, the permanent gate is re-established around the new depth. If the new depth is outside the limits of the gate, a temporary gate using the same gate parameters is set up around the depth. If the next depth is within the permanent gate, the depth inside the temporary gate is discarded. If, however, the next depth is inside the temporary gate, the temporary gate is re-established around the depth. If the number of depths through the temporary gate is equal to the user-defined gate length, the temporary depths are accepted and the permanent gate is re-defined around the last depth inside the temporary gate. Each second the shallowest good depth is recorded.

The gate is initialized by establishing a temporary gate around a number equal to the minimum depth plus one decimetre. When the first depth is read, the temporary gate will be re-defined, and if the data is good a permanent gate will eventually be set up.

The values used for gate width and gate length are important. If the gate is too narrow or too long, bottom detail may be ignored; if the gate is too wide or
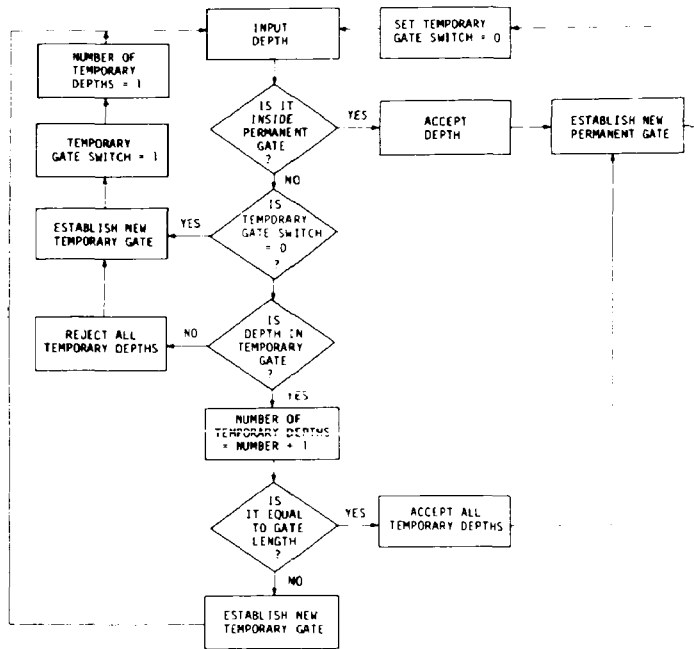
FIG 10. — Depth filter.

too short, bad data may be accepted. The gating technique does not work well on a steep slope where each succeeding depth is out of gate and none are selected. This can be solved by expanding the gate width, but this could allow bad depths to be accepted.

Position Filter

If the depth filter is used correctly, the hydrographer will record reasonably clean depth data. This is not much good to him unless his positions are reliable. In the Canadian Hydrographic Service there are mainly two areas that cause problems.

On continuous-wave, phase comparison systems, such as Seafix or Minifix, weak signals or atmospheric and RF interference can cause lane jumps. Receivers are set at a reference buoy before sounding operations begin and are checked any time interference is suspected and at the end of each work day. This may mean the survey vessel has to steam a number of miles to a reference point each time a positioning problem is suspected, resulting in lost survey time. If a pattern change goes undetected until the end-of-day check, it may result in today's work being repeated tomorrow.

Except for system calibration and phase shifts, the pattern reading is correct as long as the signals are phase-locked. After calibration, the readings may vary with phase shifts which can be caused by changes in temperature, humidity or atmospheric conditions. These phase shifts are monitored throughout the survey and corrections are applied to pattern readings. So, essentially, the only error

check required for this type of positioning system is to detect when the receiver has lost lock with one or more of the shore stations.

Here is how the NAVBOX miniprocessor checks for lost-lock conditions (see fig. 11). Pattern readings for one second are averaged and compared to the average of the previous second. If the difference exceeds the distance the vessel can travel in one second, an alarm is triggered. This distance, in portions of a lane on the baseline, is a variable that is entered by the hydrographer. Bad pattern values are set to zero for recording, the last good pattern reading is printed out, and subsequent bad values are printed until no more lane jumps are detected. If the period of pattern instability is short, the pattern value can be reset by using the printed values to derive a lane correction. This saves a long voyage to a reference point. The software filter is also a good indicator of pattern stability. But there may be a tendency for the hydrographer to expand the filter parameter until jitter caused by faulty cables, antennas, transmitters or receivers
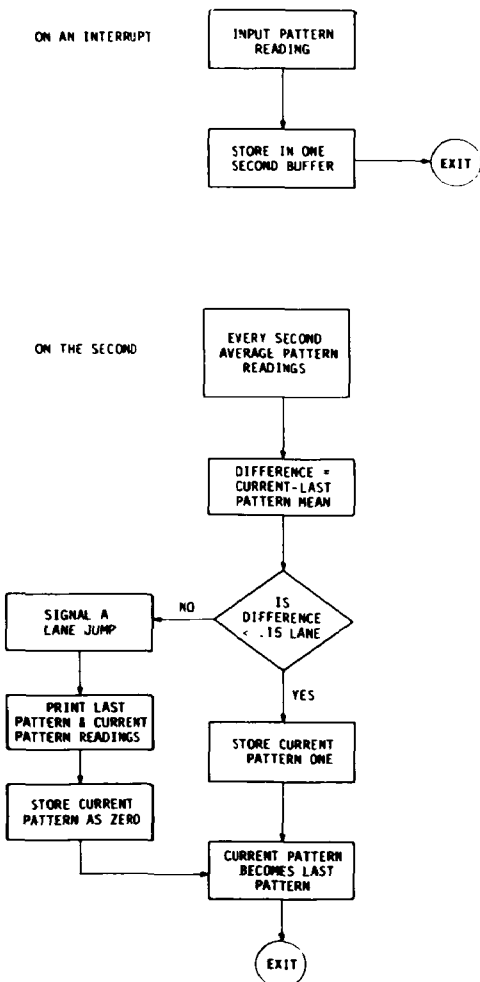
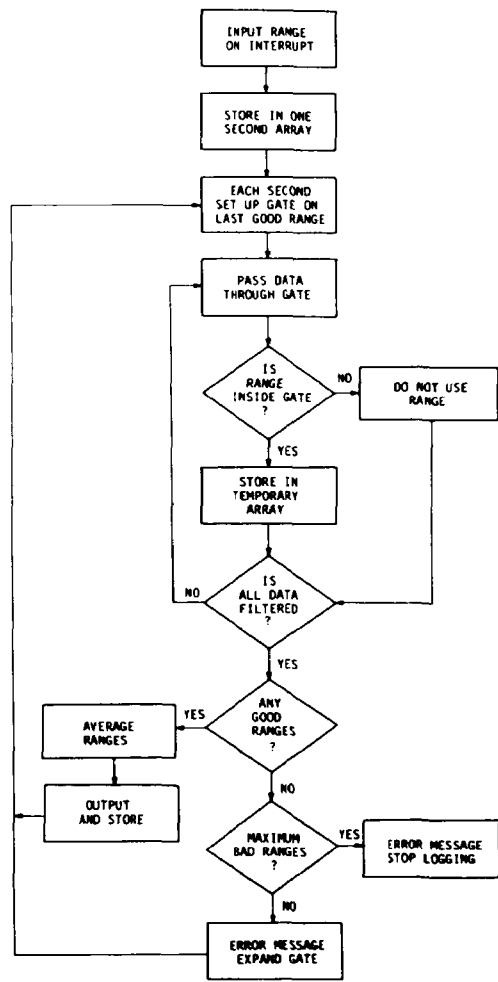FIG. 11. – Lane jump filter.   FIG. 12. – Range filter.

is ignored by the filter while lane jumps are still detected. This is not a recommended practice since unstable patterns means a fault needs to be repaired.

Systems that operate on the basic principle of pulse radar, such as Motorola RPS and Mini-Ranger, can produce range jumps of ± 4 metres at a stationary receiver. The ranges, which can be affected by signal reflections and cancellations, are filtered by the NAVBOX (see fig. 12). Each distance received during one second is stored in a temporary buffer. A symmetrical gate is established around the average of the good ranges acquired during the previous second, and distances within the gate limits are averaged. The gate width is based on the maximum distance the survey vessel can travel in one second. If none of the distances are within the gate, the gate is expanded by an amount proportional to the rate of change of the range. If the range is not reacquired within the user-defined maximum time, known as gate length, an alarm is activated. Once again, gate values are important. If the gate is too narrow, good ranges will be expelled and the NAVBOX will not navigate. If the gate is too wide, excessive range instability will go unnoticed.

Why are the depth filter and range filter algorithms different ? As the launch moves in a straight line the ranges increase or decrease at a predictable rate. If no acceptable data is available for one second it makes sense to expand the gate by the same rate, though a limit on the number of times the gate may be expanded is required to ensure that the NAVBOX does not accept bad ranges, but, instead, informs the hydrographer that good ranges must be reacquired.

However, depths do not behave in the same manner. They may remain constant on a flat bottom, change gradually or abruptly on a rough bottom, but they seldom change at a constant rate. Gate expansion, then, is not a logical depth filter parameter. The temporary gate technique is introduced so that the permanent gate will not be forsaken until a reasonable number of depths are found out of gate.

NAVBOX APPLICATIONS

The NAVBOX has many real and potential applications. The most important, as far as the hydrographer is concerned, is to run survey lines. These can be run in any direction, are parallel and straight, make planning easy and the survey more efficient, and can be easily modified at any time during the work day.

The NAVBOX can be used to guide the survey vessel to the survey area and back home again, by simply entering the present position and the destination (see fig. 13). NAVBOX will indicate in which direction to travel, keep the user on line, and tell him when he gets there. This is the perfect opportunity to run check lines, and it is very useful when visibility deteriorates.

In point to point operation, the NAVBOX will guide the vessel between predetermined points along pre-determined lines. This is useful when performing bottle casts, collecting bottom samples, or conducting similar scientific projects. It is used in the Arctic where spot soundings are required at regular intervals over ice-covered waters. In another version of the point to point mode, a number of
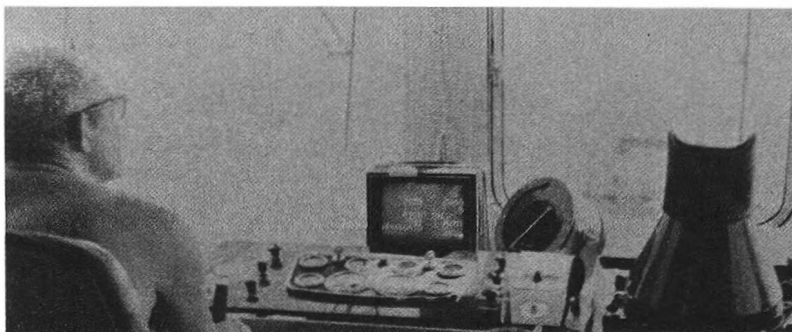
FIG. 13. – NAVBOX can be used to guide the survey vessel.

points may be entered and stored in memory. As each point is recalled (a push button operation), the NAVBOX indicates the direction to steer and distance to travel, then guides the vessel to that point. This is very useful during shoal examinations, if the co-ordinates of each shoal indication to be examined are entered. Once the peak of the shoal has been determined, it is a simple matter with the NAVBOX to run a tight grid over the shoal to delineate the shape.

The NAVBOX is potentially useful to dredging contractors for line-keeping, or to surveyors for checking the work of dredging contractors. It can be used for line-keeping during side scan sonar or sweep surveys, where the grid pattern is extremely important. Or it could be used for line-keeping during the installation of submarine pipelines and cables.

But it need not be restricted to straight line applications. Drogue positions, during a current survey, for instance, could easily be logged on the NAVBOX. Or it can simply tell the user his position.

As you can see, NAVBOX can be a versatile instrument, limited only by the ingenuity of the user. And if it does not perform the required operation, software changes are possible. These could include changes to convert positions to latitude and longitude instead of grid co-ordinates, or changes to accept other types of positioning systems.

CONCLUSION

The NAVBOX has been used in a production capacity since its inception in 1977. It has been used in the Arctic on tracked vehicles (see fig. 14) and helicopters (see fig. 15) where bitter cold and excessive vibration did not inhibit its performance. The NAVBOX has been used on board hydrographic and geolimnological survey vessels from Lake Erie to Lake Huron, from Georgian Bay to Lake Nipissing and is being used for the first time in 1980 in Quebec and on the Atlantic and Pacific coasts (see fig. 16).
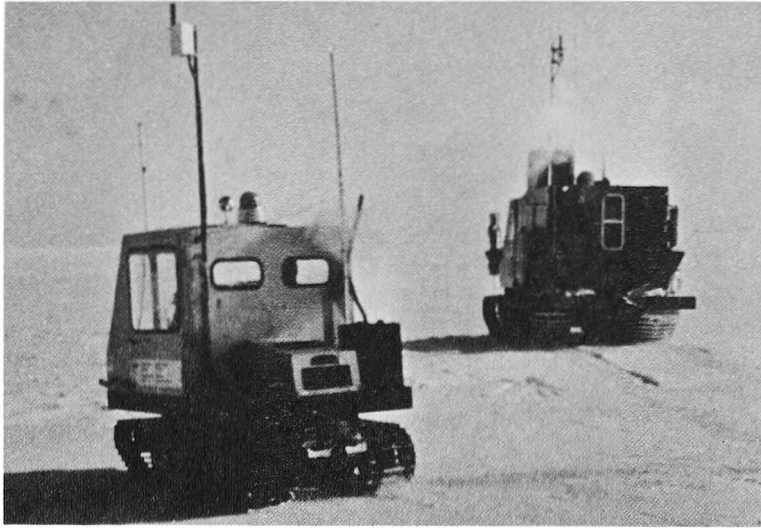
FIG. 14. — Tracked vehicles used in the Canadian Arctic.

FIG. 15. — Helicopters used in the Canadian Arctic.

As part of a Canadian government program to transfer technology to the private sector, NAVBOX units are being produced commercially in Canada and are available to anyone that wants to buy one. Private and public survey organizations and dredging contractors have shown a large interest both nationally and internationally.

Though a few hydrographers may be inclined to rely on the tried and true methods, most hydrographers feel there is a need for systems like NAVBOX and
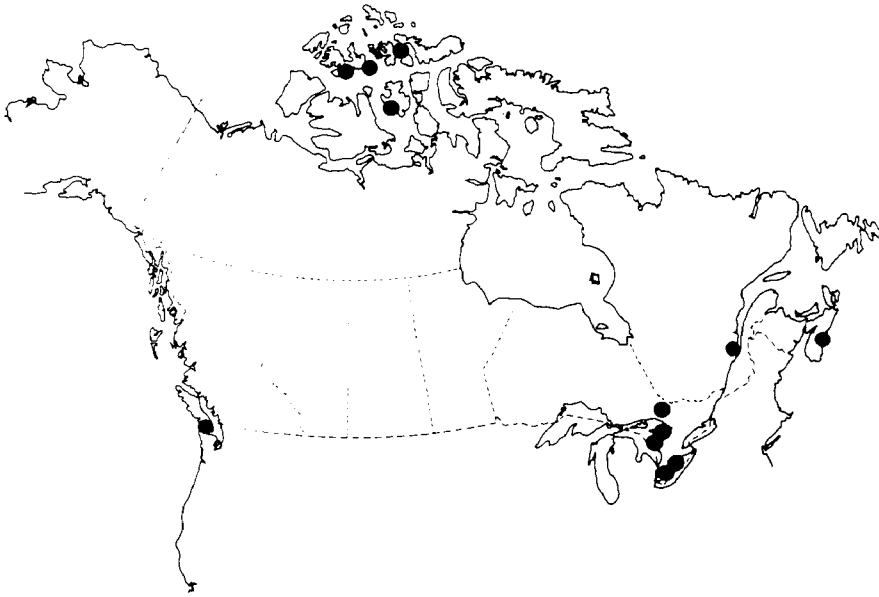
FIG. 16. — NAVBOX deployment 1977 to 1980.

lend their support to similar projects. Hydrographers should be involved directly in the design and implementation of new systems that are being developed specifically for their use. This will help to remove some of the mystique surroun- ding development projects. Every hydrographer should completely understand the capabilities and limitations of a system before he uses it. No system, not even the NAVBOX, is fool-proof.